A METHOD TO ATTRIBUTE FATALITIES AND COSTS TO SPECIFIC INJURIES

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ABSTRACT

A data-driven procedure is presented to estimate the costs and the number of fatalities attributable to specific types of injuries. It continues Martin and Eppinger's work presented at the 2003 ESV conference. The procedure examines a crash victim's entire injury record in the process. All possible injuries are denoted by unique codes as described in the AIS Injury Coding Manual. The two most serious injuries – denoted as the primary injury and the secondary injury – are chosen from the injury record and are used to characterize a victim's entire set of injuries. When the mortality rate of the primary injury code is combined with that of the secondary injury, an overall fatality risk is obtained. Fatalities attributable to specific injuries may then be determined by considering the effect that a specific injury or set of injuries has on fatality risk. Attributable costs are estimated in a similar manner. Ultimately, this process – which singles out specific injuries – provides a means to determine the types of injuries NHTSA should strive to prevent, and to determine the capabilities needed of a crash dummy to ascertain whether such injuries are sustainable in a crash test.

INTRODUCTION

The National Highway Traffic Safety Administration (NHTSA) is responsible for reducing deaths, injuries, and economic losses resulting from motor vehicle crashes. This is accomplished in part by setting and enforcing safety performance standards for motor vehicles. The performance of a vehicle in mitigating injuries is assessed through the Federal Motor Vehicle Safety Standard (FMVSS) 200 series. Injury potential is measured through the use of a crash test dummy exposed to collision forces.

This paper focuses on the process and procedure of determining costs and fatalities attributable to specific types of injuries. A means of ranking the importance of specific types of real world injuries is presented. Such rankings are intended to be used to determine the types of injuries NHTSA should strive to prevent and the measurements required of a crash dummy to ascertain whether such injuries are sustainable in a crash test. Eventually, the methodology may be used to justify dummy requirements by providing estimates of lives saved and injuries prevented that may be achieved by implementing a new safety countermeasure.

OBJECTIVE

In searching for the appropriate metrics to be used in crashworthiness assessments with dummies, NHTSA takes a data driven approach to assure that its use in a federal regulation will lead to a significant reduction in injuries. Within NHTSA's biomechanics division, real-world data is used to help make three important determinations that are used to guide research priorities:

1. Determine the types of injuries that NHTSA should strive to prevent.

2. Determine the measurements required of a crash dummy to ascertain whether such injuries are sustainable in a crash test.

3. Provide an estimate of the number of lives that may be saved under a given performance requirement to prevent such injuries.

Generally, there must be enough existing data to show that a proposed vehicle performance requirement (such as implementing a new injury metric) will reduce the risk of injuries significantly. To aid in such assessments, NHTSA maintains epidemiological data on the nature, causes, and injury outcomes of crashes.

National Automotive Sampling System – Crashworthiness Data System

The Crashworthiness Data System (CDS) is one of the epidemiological databases maintained by NHTSA [1]. The CDS is a nationally representative probability sample of police-reported automobile crashes in the United States. CDS cases are limited to crashes that involve at least one passenger vehicle that was towed from the crash scene due to damage resulting from the crash. Each case is assigned a weighting factor that represents an estimate of the number of like-mannered cases that occurred during the sample year. This paper offers a new means with which to interpret CDS data by examining costs and fatalities attributable to specific types of injuries.

METHODS

Injury Coding.

Within the CDS, injuries to motorists are described by using a seven digit code in accordance with the CDS Injury Coding Manual [2]. This manual is adopted from a very similar manual developed by AAAM titled "The Abbreviated Injury Scale (AIS) Injury Coding Manual" [3]. The CDS manual provides codes for over a thousand distinct injury types. It gives synonyms, parenthetical descriptions of each code. In theory, the manual provides codes for every possible injury that one could sustain in a motor vehicle crash.

CDS injury codes may be cross-referenced with detailed nomenclature in the coding manual. The first digit of the code identifies the body region; the second digit identifies the general anatomic structure; the third and fourth digits identify the specific anatomic structure or, in the case of injuries to an external region, the specific nature of the injury; the fifth and sixth digits identify the level of injury within a specific body region and anatomic structure; the seventh digit is a general severity level referred to as the AIS score. AIS scores take on integer values of 1 (low severity) to 6 (maximum). If a motorist suffers an injury of an unknown severity, a score of 7 is assigned.

Computing Mortality Rates.

Determining the number of fatalities attributable to a particular type of injury is a multi-step process. The first step is to determine the mortality rate associated with each injury. The basis of determining the mortality rate values is fully described by Martin and Eppinger (2003b). mortality rate values are akin to the AIS severity scores of 1-6. But unlike AIS scores, unique mortality rate values ranging from 0 to 1 are computed for each 7-digit code (although some codes describing very similar injuries share the same values). Moreover, the basis of the values is the CDS data itself rather than the findings of an expert panel (who assign the severity scores to each of the six-digit codes). The mortality rate for a given code is: one minus the ratio of the number of times it was reported to be the cause of death over its overall incidence, as illustrated in Fig. 1.

Values of the mortality rates for all AIS codes used in the analysis presented herein are given in the Appendix. Mortality rates are given for injuries described by a condensed five-digit AIS code which is created by dropping the injury level identifiers (digits five and six) from the seven-digit code. In doing so, it is assumed that two or more injuries with different seven-digit codes but sharing the same five-digit code have the same mortality rate. The five-digit code is reasoned to sufficiently describe injuries that are unique in the context of crashworthiness research. That is, there is no need to discriminate among the injury levels (digits 5 and 6) when considering the impact of a safety countermeasure. More importantly, the condensed codes provide better statistical correlations in ranking the codes because more CDS observations are associated with fewer codes.

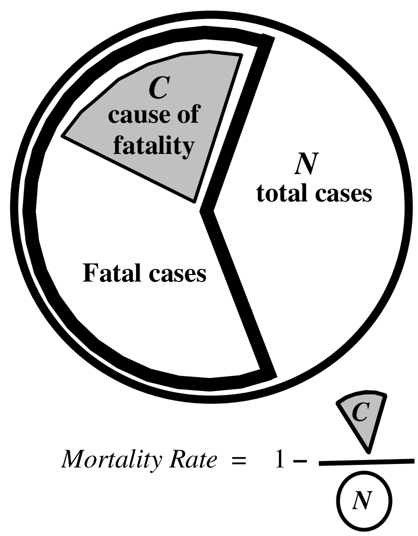

Figure 1. Computing mortality rates for individual injuries.

The overall fatality rate of a particular set of injuries is a function of the mortality rate of each injury sustained. Like the mortality rates themselves, the means to compute the overall fatality rate of a given accident victim who sustains several injuries is presented by Martin and Eppinger [4, 5]. In short, only the two most serious injuries – the primary injury and secondary injury – are used to characterize a victim's entire injury record. Thus, instead of using just a single maximum AIS (or MAIS) injury, the "Primary/Secondary" model uses two injuries. Whereas the primary injury sets the upper limit of the fatality probability, the secondary injury can be thought of as a "survivability modulator".

This two-injury approach uses the actual CDS outcomes to help select and sort injuries. So, not only are the mortality rates used to compute overall fatality rate, they are used to select which two injuries are chosen to represent the injured victim in the first place. Generally, all other injuries have very little effect on the overall fatality rate and are excluded from the fatality function. For example, a Primary/Secondary/Tertiary model produces only a slightly lower (though not significantly lower) deviance than the Primary/Secondary model alone.

Also, in the analysis described herein all injuries with severity scores of AIS=1 are assigned mortality rates of zero. That is, a victim with only AIS 1 injuries is treated as having no injuries at all. The mortality associated with crash victims having only AIS 1 injuries is known to be extremely low; this is not necessarily the case for all AIS 2+ injuries.

Computing Attributable Fatalities.

Attributable fatalities are the number of lives lost due to a particular injury. For example, consider a hypothetical five-case dataset shown in Table 1. Each case represents a CDS occupant who sustained up to five injuries, at least one of which was a head injury. The number of fatalities due to head injuries alone may be estimated by taking two "sweeps" through the dataset as described below:

Sweep 1. The upper table in Table 1 represents the actual five-case dataset. Examine the injury record of each case. Associated with each injury code is a mortality rate which can be found in the Appendix (head injuries have codes with a "1" as the first digit). By using the Appendix as a lookup table, select the code having the highest mortality rate (the primary injury, Pinj) and the code having the next highest rate (the secondary injury, Sinj).

Compute the overall fatality probability for the case, Pfatal. The form of the fatality rate function is given in Eq. 1. The values of the parameter estimates (β's in Eq. 1) are determined by optimization process that when given the actual mortality produces the best estimates (lowest deviance) of the probability of fatality.

$$Pfatal = (MR\_Pinj)^\wedge(\beta_1) * (MR\_Sinj)^\wedge(\beta_2) \quad [1]$$

where MR_Pinj and MR_Sinj are the mortality rates associated with the top two injuries (from lookup table in Appendix), while $\beta_1 = 0.382$ and $\beta_2 = 1.014$ (from the optimization process).

In Table 1, "case wgt" is the CDS national expansion factor for each case. The product of the probability and the case weight is an estimate of the number of fatalities that occurred in the U.S. for occupants having those types of injuries during the sample year. The total fatalities involving head injuries is found by summing the five estimates. The sum, 1446, is an estimate of fatalities involving (by not necessarily attributed to) head injuries.

Sweep 2. Examine the injury record again, only this time strike from the injury record all head injuries, as shown in the lower table in Table 1. From the remaining injury codes, a new Pinj, Sinj, and Pfatal are found. A new estimate of 451 fatalities is also found.

CASE	i1	i2	i3	i4	i5	Pinj	Sinj	PFatal	CASE WGT	Fatals1
1	1406.4	5418.2	2508.2	4502.2		1406.4	5418.2	0.2689	2613.42	703
2	1402.5	1402.5	1406.4	4414.4	4502.3	1402.5	1402.5	0.7572	346.78	263
3	1402.5	1608.5	8518.3	2908.2		1402.5	1608.5	0.4659	394.10	184
4	1402.5	1402.5	8518.3	8520.2	8524.2	1402.5	1402.5	0.7572	210.28	159
5	1406.5	8306.2				1406.5	8906.1	0.1293	1062.97	137
									Total	1446

CASE	i1	i2	i3	i4	i5	New Pinj	New Sinj	New PFatal	CASE WGT	Fatals2
1	~~1406.4~~	5418.2	2508.2	4502.2		5418.2	2508.2	0.1603	2613.42	419
2	~~1402.5~~	~~1402.5~~	~~1406.4~~	4414.4	4502.3	4414.4	4502.3	0.0876	346.78	30
3	~~1402.5~~	~~1608.5~~	8518.3	2908.2		8518.3	2908.2	0.0011	394.10	0
4	~~1402.5~~	~~1402.5~~	8518.3	8520.2	8524.2	8518.3	8520.2	0.0010	210.28	0
5	~~1406.5~~	8306.2				8306.2		0.0012	1062.97	1
									Total	451

Table 1. Demonstration of the process to compute fatalities attributable to head injuries involving two sweeps thru the dataset: Sweep 1 (upper table) and Sweep 2 (lower table).

Finally, the fatalities attributable to head injuries is found by subtracting the results of Sweep 2 from Sweep 1: 1446 – 451 = 995. This is expressed mathematically by Eq. 2.

Attributable Fatalities =

$$\sum_{i=1}^{n}\left\{(PFatal)_i - (New\ PFatals)_i\right\}\cdot(casewgt)_i \qquad [2]$$

The result provided by Eq. 2, 995 lives, is an estimate of the number of fatalities attributable to head injuries in the U.S. for all like-mannered cases.

Computing Attributable Costs.

Computing the costs attributable to a particular injury follows a similar methodology as attributable fatals. The procedure starts with cost per injury estimates presented by Zaloshnja et al [6], who have reasoned that the cost associated with the MAIS injury is the approximate cost incurred by the victim. Their costing methodology is an averaging process: it is understood that most victims suffer multiple injuries, and all injuries contribute to the overall cost. Nonetheless, their methodology offers a reasonable means to account for injury costs.

The methodology described herein takes the Zaloshnja et al process a step further. For victims who sustain multiple injuries (such as the vast majority of CDS MAIS 2+ victims), it provides a means to isolate the costs due to a particular type of injury from costs borne by other injuries.

For example, consider head injuries again. The costs due to head injuries alone may be estimated by taking two "sweeps" through the dataset as described below:

<u>Sweep 1</u>. Examine the injury record of each case in the upper table of Table 2. Associated with each injury code is a cost figure which can be found in the Appendix. By using the Appendix as a lookup table, select the code having the highest cost. An overall case cost is taken as the cost corresponding to this most expensive injury. (This may or may not be the same as the MAIS injury or the injury having the highest mortality rate). The product of the case cost and the case weight is an estimate of the costs incurred in the U.S. for occupants having those types of injuries during the sample year.

<u>Sweep 2</u>. Examine the injury record again, only this time strike from the injury record all head injuries, as shown in the lower table of Table 2. From the remaining list of injuries, find the case cost as in Sweep 1.

Total costs attributable are found by performing this operation for every case, and summing the differences: 9.62 – 0.68 = $8.94 Million. Mathematically, this is expressed as shown in Eq. 3:

CASE	i1	i2	i3	i4	i5	Case Cost $k	Case Wgt	Cost1 $M
1	1406.4	5418.2	2508.2	4502.2		1201	2613.42	3.14
2	1402.5	1402.5	1406.4	4414.4	4502.3	3219	346.78	1.12
3	1402.5	1608.5	8518.3	2908.2		3219	394.10	1.27
4	1402.5	1402.5	8518.3	8520.2	8524.2	3219	210.28	0.68
5	1406.5	8306.2				3219	1062.97	3.42
							Total	9.62

CASE	i1	i2	i3	i4	i5	Case Cost $k	Case Wgt	Cost2 $M
1	~~1406.4~~	5418.2	2508.2	4502.2		139	2613.42	0.36
2	~~1402.5~~	~~1402.5~~	~~1406.4~~	4414.4	4502.3	259	346.78	0.09
3	~~1402.5~~	~~1608.5~~	8518.3	2908.2		244	394.10	0.10
4	~~1402.5~~	~~1402.5~~	8518.3	8520.2	8524.2	237	210.28	0.05
5	~~1406.5~~	8306.2				79	1062.97	0.08
							Total	0.68

Table 2. Demonstration of the process to compute costs attributable to head injuries involving two sweeps thru the dataset: Sweep 1 (upper table) and Sweep 2 (lower table).

Attributable Costs =

$$\sum_{i=1}^{n} \{Cost1)_i - (Cost2)_i\} \cdot (casewgt)_i \qquad [3]$$

Thus, $8.94 Million is an estimate of the costs saved if all head injuries could be eliminated.

The overall fatality probability is also used in this analysis. Zaloshnja et al [6] provide a cost associated with a fatality that is the same regardless of the injuries. When evaluating a CDS case whose outcome is a fatality, the overall mortality rate is re-computed after "removing" the head injury from the record in Sweep 2. If the fatality rate decreases by more than 80%, it is assumed that the occupant would have lived, and the overall cost ("Cost2") is computed as such. If the fatality rate is more than 80% of the actual even after the head injuries are "removed", then the victim is assumed to still have suffered fatal injuries and no costs are attributed to the head injuries.

APPLICATION

To demonstrate the utility of the process, consider the costs due to and fatalities attributable to head injuries in side impacts. The study herein is based on a working data set extracted from 1997-2003 CDS files. The data set composition is limited to the following:

* Vehicles of model year 1998 or later
* Near-side occupants in a side impact collision (front or rear seat)
* Adults restrained by a properly worn seat belt.

In all, the working data set contains data on 313 crash victims – including records for more than 51 fatalities – over the seven-year span. When these figures are weighted to represent national totals, there are 30,737 crash victims and 2,164 fatalities over the seven years. Among the fatalities, 825 have head injuries of AIS ≥ 2.

RESULTS

Attributable Fatalities

The number of fatalities attributable to head injuries is found by taking two sweeps through the dataset as described earlier. In the first sweep, only the *n* cases where a head injury exists among the top two are retained. The mortality rates of these the injury codes are found in the lookup table (see appendix). In the second sweep, only the *n* cases are examined, but injury codes associated with head injuries are disregarded. This gives rise to a new fatality estimate, from which the number of fatalities attributable to head injuries is determined to be 651, as denoted in Table 3.

Attributable Costs

The costs attributable to head injuries may also be determined by taking two sweeps through the dataset as described earlier. In the first sweep, only the *n* cases where a head injury was the costliest of injuries are retained. The costs associated with these cases corresponds to the cost rates (found in the lookup table in the Appendix) of the *n* head injuries. In the second sweep, only the *n* cases are examined, but injury codes associated with head injuries are disregarded, and a new estimate of overall costs is determined. Costs attributable to head injuries are then found to be $5,372 million.

The same methodology may also be used to determine costs and fatalities attributable to specific types of head injuries, like simply brain injuries as opposed to head injuries that include skull fractures. Table 3 provides the estimates for both instances when the two-sweep process is carried out.

1. Fatalities in which an AIS 2+ head injury was sustained.	825
2. Fatalities attributable to head injuries.	651
3. Costs due to head injuries ($Million).	5,372
4. Fatalities attributable to brain injuries.	430
5. Costs due to brain injuries ($Million).	4,948

Table 3. Cumulative costs and fatalities attributable to head and brain injuries in the U.S.; belted adults in near-side crashes, MY '98+ vehicles. Source: 1997-2003 CDS.

DISCUSSION

A simplistic analysis of CDS data merely provides frequency counts of injuries; it does not explicitly explain how many lives may be saved if a given type of injury could be avoided. For example, Table 3 shows that 825 fatal crash victims received a head injury of AIS ≥ 2. While the head injury probably contributed to the fatal outcome in most of the cases, there were injuries in other body regions, too. As such, the CDS does not provide a direct estimate of fatalities due to head injuries. For a more exacting estimate, the two-injury characterization (described earlier in the "Methods" section) may be used to find the number of fatalities that are directly attributable to head injuries

Aside from the example presented above for head injuries, this methodology may be carried out to examine a variety of injury types that may provide insights on safety priorities and research programs. Some additional ideas are given below.

1. Abdominal organ injuries. There is a lack of basic biomechanical knowledge of thresholds and mechanisms associated with abdominal injuries largely due to the difficulty in observing such injuries in laboratory experiments. As a result, it may be difficult to correlate ATD instrumentation with abdominal organ injuries per se. Under the scheme presented herein, one may examine costs and fatalities due to abdominal organ injuries that occur in the absence of other types of injuries (like rib injuries) that *are* well correlated with ATD instrumentation measurements. If significant costs are found to be borne by abdominal organ injuries alone, then it may justify a research program to investigate thresholds, injury mechanisms, and development of appropriate ATD instrumentation.

2. Thoracic injury types. Side impact ATD's use rib deflection sensors to assess potential for thoracic injury. Moreover, the criteria for thoracic injury potential as measured by ATD rib deflections is largely based on the number of broken ribs observed in tests with post-mortem human surrogates. With the methodology presented herein, one may look for thoracic organ injuries with and without significant rib fractures to gain insights into whether rib deflection measurements adequately gauge thoracic trauma.

3. Knee-Thigh-Hip injuries. NHTSA is monitoring and investigating occult injuries from frontal crashes. Knee-thigh-hip (KTH) complex injuries to belted occupants are one of the injury patterns being investigated. By singling out each of these three lower extremity body regions, one may examine the makeup of knee vs. thigh vs. hip and pelvis injuries in order to gain insights into biofidelity requirements of a dummy KTH assembly and the need for, say, acetabular measurements in an ATD.

4. Children in Child Restraint Systems. NHTSA has addressed the TREAD Act by incorporating new requirements into FMVSS No. 213, including improved child test dummies. Moreover, Anton's Law requires the development of an anthropomorphic test device simulating a 10-year-old child and an evaluation of integrated child restraint systems. The general injury distributions of children in CRS may be examined in frontal and side crashes in an effort to examine the body regions most apt to be injured. This may help pinpoint the performance requirements of child dummies under various test conditions.

Results of these example studies are beyond the scope of this paper, but may be presented in the future.

Ongoing Enhancements to the Methodology

<u>Mortality Rates</u>. As described earlier, an optimization process is used to determine the coefficients (β_1 and β_2) of the overall fatality function such that overall deviance is minimized when considering the actual outcomes of each case. Theoretically, the mortality rates may be optimized, too, and a process is being implemented to do so.

<u>Costs per Injury.</u> Similar to the optimization process used for mortality rates, a process to provide cost per injury estimates based on NHTSA epidemiological data is ongoing. Data from the Crash Injury Research and Engineering Network (CIREN) is being considered for this effort (CDS does not contain cost data).

While CIREN contains medical and rehabilitation costs, the costs described in the paper herein are comprehensive costs, which are more general and far-reaching. Nonetheless, Zaloshnja et al [6] also list the cost per injury for medical costs only (besides providing the comprehensive costs used herein.) It may be possible to compare CIREN-based costs with Zaloshnja's medical costs in an effort to better understand total costs to motor vehicle crash victims.

<u>Cost of Fatalities</u>. The current methodology uses the arbitrary decision to recode "fatalities" as "survivals". Recall Sweep 2 of the cost estimation process for fatal cases: if the overall fatality rate decreases by more than 80% once the "attributable" injuries are stuck, the outcome is assumed to be "nonfatal". An new approach is being worked out whereby the CDS case weight for a fatal case is prorated between "fatal" and "surviving" categories in proportion to the fatality rate decrease.

SUMMARY

The study presented herein provides a new means to interpret epidemiological injury data in a way that complements crashworthiness research. It is meant to help researchers predict how many lives may be saved by a prospective safety countermeasure that is designed to mitigate specific types of injuries. Specifically, this injury-accounting scheme has been developed to help fulfill three basic objectives:

1. Determine the types of injuries that NHTSA should strive to prevent.
2. Determine the measurements required of a crash dummy to ascertain whether such injuries are sustainable in a crash test.
3. Provide an estimate of the number of lives that may be saved under a given performance requirement to prevent such injuries.

One of the difficulties in using CDS data is that the characterization of injured motorists is not usually clear-cut. For each CDS occupant injury record, there are sometimes over twenty injuries spread over multiple body regions that are listed. This makes it difficult to judge how likely it is that a life will be saved if a specific injury is mitigated.

This paper offers a new perspective in interpreting CDS injury data. It describes a procedure to estimate the risk to life that multiple injuries pose to crash victims and to estimate the costs borne by and the number of fatalities attributable to specific types of injuries. For example, if one desires to estimate the number of lives saved if a particular injury is mitigated, it may be accomplished forthrightly under the scheme described herein. This is much harder to accomplish in the context of MAIS which does not account for multiple injuries.

Ultimately, this process – which singles out specific injuries – provides a means to determine the types of injuries NHTSA should strive to prevent, and to determine the capabilities needed of a crash dummy to ascertain whether such injuries are sustainable in a crash test.

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APPENDIX. Costs and mortality rates by injury.

5-Digit AIS Code	Nomenclature	Mort. Rate	Comprehensive Costs Year 2000 $
1130.6	Head Crush	1.000	3,158,552
1150.7	Closed head	0.961	3,218,776
1159.7	Closed Head	1.000	3,158,552
1204.5	Basilar artery	0.373	3,218,776
1210.3	Internal carotid	0.070	613,078
1212.4	Intracranial vessel	0.600	1,201,008
1214.3	Middle cerebral	0.150	613,078
1214.4	Middle cerebral	0.700	1,201,008
1216.4	Other head	0.654	1,201,008
1228.3	Vertebral artery	1.000	613,078
1228.5	Vertebral artery	1.000	3,218,776
1306.2	Optic nerve	0.001	289,674
1308.2	Oculomotor nerve	0.000	289,674
1310.2	Trochlear nerve	0.000	289,674
1314.2	Abducens nerve	0.001	289,674
1316.2	Facial nerve	0.000	289,674
1402.5	Brain stem	0.842	3,218,776
1402.6	Brain stem	1.000	3,158,552
1404.3	Cerebellum contus.	0.881	613,078
1404.4	Cerebellum contus.	0.881	1,201,008
1404.5	Cerebellum hematom	0.881	3,218,776
1406.3	Cerebrum contusion	0.068	613,078
1406.4	Cerebrum contusion	0.068	1,201,008
1406.5	Cerebrum contusion	0.220	3,218,776
1407.3	Pituitary injury	0.002	613,078
1500.2	Skull fracture	0.912	310,706
1502.3	Basilar skull	0.258	374,314
1502.4	Basilar skull	0.987	1,042,399
1504.2	Vault skull	0.000	310,706
1504.3	Vault skull	0.698	374,314
1504.4	Vault skull	0.976	1,042,399
1602.2	LOC	0.000	289,674
1604.2	Awake at scene	0.000	289,674
1604.3	Awake at scene	0.001	613,078
1606.2	Lethargic, Stuporous	0.001	289,674
1606.3	Lethargic, Stuporous	0.025	613,078
1608.3	Unconscious at scene	0.001	613,078
1608.4	Unconscious at scene	0.018	1,201,008
1608.5	Unconscious at scene	0.541	3,218,776
1610.2	Cerebral Concussion	0.000	289,674
1906.2	Scalp laceration	0.166	186,330
1908.2	Scalp avulsion	0.001	186,330
1908.3	Scalp avulsion	0.002	303,727
2150.7	Blunt Facial	0.000	303,727
2202.3	External cartoid	0.000	303,727
2404.2	Eye avulsion	0.001	246,807
2412.2	Sclera laceration	0.001	246,807
2502.2	Alveolar ridge	0.004	186,330
2506.2	Mandible fracture	0.000	88,575
2508.2	Maxilla fracture	0.001	88,575
2508.3	Maxilla fracture	0.035	119,096
2508.4	Maxilla fracture	0.350	520,070
2510.2	Nose fracture	0.001	88,575
2512.2	Orbit fracture	0.001	88,575
2512.3	Orbit fracture	0.001	119,096
2516.2	Temporomandibular	0.001	88,575
2518.2	Zygoma/malar fx	0.001	88,575
2906.2	Facial Skin	0.001	186,330
2906.3	Facial Skin	0.001	303,727
2920.3	Face Burn	0.001	787,813

5-Digit AIS Code	Nomenclature	Mort. Rate	Comprehensive Costs Year 2000 $
3150.7	Blunt neck/throat	0.000	460,991
3202.3	Carotid (common)	0.149	460,991
3208.2	Jugular vein	0.019	63,930
3210.2	Vertebral artery	0.002	63,930
3402.2	Larynx contusion	0.001	63,930
3406.2	Pharynx laceration	0.000	63,930
3414.2	Thyroid gland	0.004	63,930
3418.2	Vocal cord	0.001	63,930
3502.2	Hyoid fracture	0.001	63,930
3906.2	Neck/Throat Skin	0.001	186,330
4130.6	Chest Crush	1.000	3,158,552
4150.7	Blunt chest inj	0.664	674,183
4159.7	Blunt chest inj	1.000	3,158,552
4202.4	Aorta, thoracic	0.917	258,648
4202.5	Aorta, thoracic	1.000	536,993
4202.6	Aorta, thoracic	1.000	3,158,552
4208.5	Coronary artery	0.459	536,993
4210.3	Pulmonary artery	0.141	147,277
4212.3	Pulmonary vein	0.396	147,277
4212.4	Pulmonary vein	0.557	258,648
4214.3	Subclavian artery	0.148	147,277
4216.3	Subclavian vein	0.250	147,277
4216.4	Subclavian vein	0.719	258,648
4218.3	Vena Cava	0.203	147,277
4218.4	Vena Cava	1.000	258,648
4220.2	Chest vessel	0.000	107,754
4222.2	Chest vessel	0.002	107,754
4406.2	Diaphragm NFS	0.001	107,754
4406.3	Diaphragm lac.	0.101	147,277
4406.4	Diaphragm rupture	0.189	258,648
4408.5	Esophagus laceration	0.801	875,404
4410.3	Heart (Myocardium)	0.363	147,277
4410.4	Heart (Myocardium)	0.924	258,648
4410.5	Heart (Myocardium)	1.000	536,993
4410.6	Heart (Myocardium)	1.000	3,158,552
4412.5	Intracardiac valve	1.000	536,993
4413.5	Intraventricular	1.000	536,993
4414.3	Lung contusion	0.000	147,277
4414.4	Lung contusion	0.596	258,648
4414.5	Lung laceration	1.000	536,993
4416.2	Pericardium lac.	0.039	107,754
4416.5	Pericardium hernia	1.000	536,993
4418.2	Pleura laceration	0.000	107,754
4418.3	Pleura laceration	0.122	147,277
4422.3	Thoracic cavity	0.327	147,277
4422.5	Thoracic cavity	0.545	536,993
4424.2	Thoracic duct	0.000	107,754
4426.3	Trachea	0.000	460,991
4426.4	Trachea	0.040	258,648
4426.5	Trachea	1.000	875,404
4502.2	Rib cage	0.264	75,621
4502.3	Rib cage	0.264	103,822
4502.4	Rib cage	0.515	205,244
4502.5	Rib cage	0.970	421,043
4508.2	Sternum fracture	0.000	75,621
4906.2	Chest Skin	0.000	62,210
4920.2	Chest burn	0.000	64,198
5150.7	Abdominal trauma	0.131	261,395
5159.7	Abdominal trauma	0.001	3,158,552
5202.4	Aorta, abdominal	0.819	203,909

APPENDIX, cont. Costs and mortality rates by injury.

5-Digit AIS Code	Nomenclature	Mort. Rate	Comprehen-sive Costs Year 2000 $
5202.5	Aorta, abdominal	0.998	261,395
5204.5	Celiac Artery	0.800	261,395
5206.3	Iliac artery	0.142	132,993
5206.3	Iliac artery	0.142	132,993
5206.4	Iliac artery	0.638	203,909
5212.3	Vena cava	1.000	132,993
5212.4	Vena cava	1.000	203,909
5214.3	Abdominal vessel	0.375	132,993
5214.4	Abdominal vessel	0.375	203,909
5216.3	Abdominal vessel	0.001	132,993
5404.3	Anus laceration	0.082	132,993
5404.4	Anus laceration	0.082	203,909
5406.2	Bladder contusion	0.001	54,139
5406.3	Bladder laceration	0.004	112,077
5406.4	Bladder laceration	0.342	171,914
5408.2	Colon contusion	0.001	165,765
5408.3	Colon laceration	0.001	219,745
5408.4	Colon laceration	0.615	337,291
5410.2	Duodenum contusion	0.002	165,765
5410.3	Duodenum laceration	0.002	219,745
5410.5	Duodenum laceration	0.171	629,049
5412.2	Gallbladder lac.	0.008	165,765
5412.3	Gallbladder lac.	0.097	219,745
5414.2	Jejunum-ileum cont.	0.011	165,765
5414.3	Jejunum-ileum lac.	0.011	219,745
5414.4	Jejunum-ileum lac.	0.134	337,291
5416.2	Kidney contusion	0.001	102,009
5416.3	Kidney contusion	0.154	172,317
5416.4	Kidney laceration	0.154	240,085
5416.5	Kidney hilum	0.891	527,179
5418.2	Liver contusion	0.000	139,260
5418.3	Liver contusion	0.000	155,339
5418.4	Liver laceration	0.175	253,760
5418.5	Liver laceration	1.000	473,415
5418.6	Liver laceration	1.000	473,415
5420.2	Mesentery contusion	0.183	165,765
5420.4	Mesentery laceration	0.415	337,291
5422.2	Omentum contusion	0.002	54,139
5428.2	Pancreas contusion	0.001	165,765
5428.5	Pancreas laceration	0.716	629,049
5430.3	Penis laceration	0.000	112,077
5432.2	Perineum laceration	0.001	54,139
5432.3	Perineum laceration	0.001	112,077
5434.3	Placenta abruption	0.149	112,077
5436.2	Rectum laceration	0.001	165,765
5436.3	Rectum laceration	0.001	219,745
5436.4	Rectum laceration	0.200	337,291
5436.5	Rectum laceration	0.800	629,049
5438.3	Retroperitoneum	0.051	112,077
5440.2	Scrotum laceration	0.001	54,139
5442.2	Spleen contusion	0.000	109,687
5442.3	Spleen laceration	0.000	153,323
5442.4	Spleen laceration	0.134	256,896
5442.5	Spleen laceration	0.144	468,895
5444.2	Stomach laceration	0.001	165,765
5444.3	Stomach laceration	0.001	219,745
5444.4	Stomach laceration	0.250	337,291
5446.2	Testes laceration	0.000	54,139
5448.3	Ureter laceration	0.000	112,077
5450.2	Urethra laceration	0.003	54,139

5-Digit AIS Code	Nomenclature	Mort. Rate	Comprehen-sive Costs Year 2000 $
5450.3	Urethra laceration	0.015	112,077
5452.4	Uterus laceration	1.000	171,914
5906.2	Abdomen Skin	0.001	61,365
6150.7	Cervical Spine	0.862	4,371,935
6159.7	Cervical Spine	1.000	3,158,552
6302.2	Cervical Spine	0.001	186,330
6306.2	Lumbar Spine	0.000	31,372
6402.3	Cervical Spine	0.268	969,251
6402.4	Cervical Spine	0.233	3,305,283
6402.5	Cervical Spine	0.489	4,371,935
6402.6	Cervical Spine	1.000	3,158,552
6404.3	Thoracic Spine	0.055	104,511
6404.4	Thoracic Spine	0.084	2,340,375
6404.5	Thoracic Spine	0.393	2,771,402
6406.3	Lumbar Spine	0.052	104,511
6406.5	Lumbar Spine	0.272	2,771,402
6502.2	Cervical Spine	0.302	186,330
6502.3	Cervical Spine	0.302	119,096
6504.2	Thoracic Spine	0.001	267,061
6504.3	Thoracic Spine	0.001	262,311
6506.2	Lumbar Spine	0.001	31,372
6506.3	Lumbar Spine	0.001	262,311
7110.3	Upper Extremity	0.003	300,384
7130.3	Upper Extremity	0.000	300,384
7150.2	Upper Extremity	0.000	62,983
7150.7	Upper Extremity	0.000	217,029
7159.7	Upper Extremity	0.100	3,158,552
7206.2	Brachial artery	0.000	62,983
7206.3	Brachial artery	0.000	217,029
7210.3	Upper ext vessel	0.000	217,029
7304.2	Median, Radius	0.001	51,301
7404.2	Upper Ext muscle	0.001	62,983
7406.2	Upper Ext joint	0.000	62,983
7502.2	Acromioclavicle	0.001	47,445
7506.2	Elbow joint	0.000	22,808
7510.2	Shoulder joint	0.001	92,947
7510.3	Shoulder joint	0.001	168,999
7512.2	Sternoclavicular	0.001	92,947
7514.2	Carpus joint	0.001	47,445
7514.3	Carpus joint	0.149	47,445
7516.2	Acromion fracture	0.001	47,445
7518.2	Arm/wrist fx	0.044	47,445
7519.2	Forearm fracture	0.000	163,282
7520.2	Carpus fx	0.000	54,831
7522.2	Clavicle fracture	0.002	92,947
7524.2	Finger amputation	0.002	47,445
7525.2	Hand fracture	0.000	47,445
7526.2	Humerus fracture	0.000	92,947
7526.3	Humerus fracture	0.000	168,999
7528.2	Radius fracture	0.000	163,282
7528.3	Radius fracture	0.000	300,384
7530.2	Scapula fracture	0.001	92,947
7532.2	Ulna fracture	0.001	163,282
7532.3	Ulna fracture	0.001	300,384
7906.2	Upper ext skin	0.001	51,301
7908.2	Upper ext skin	0.001	51,301
7920.2	Upper ext burn	0.000	51,301
7920.3	Upper ext burn	0.139	468,162
7940.2	Degloving injury	0.001	51,301
7940.3	Degloving injury	0.001	223,097

APPENDIX, cont. Costs and mortality rates by injury.

5-Digit AIS Code	Nomenclature	Mort. Rate	Comprehen-sive Costs Year 2000 $
8110.3	Amput. below knee	0.239	237,203
8110.4	Amput. above knee	0.239	266,459
8130.2	Crush below knee	0.000	184,386
8130.3	Crush knee	0.020	266,459
8150.2	Lower Extremity	0.001	78,806
8150.7	Lower Extremity	0.001	25,501
8202.3	Femoral artery	0.000	71,388
8202.4	Femoral artery	0.300	550,548
8206.2	Popliteal artery	0.001	28,803
8206.3	Popliteal artery	0.021	185,689
8208.3	Popliteal vein	0.000	185,689
8210.3	Low ext vessel	0.001	120,078
8304.2	Sciatic nerve	0.001	78,806
8306.2	Femoral/tibal nerve	0.000	78,806
8404.2	Collateral ankle	0.001	122,139
8404.3	Posterior cruciate	0.001	185,689
8406.2	Lower Ext muscle	0.001	28,803
8408.2	Lower Ext tendon	0.000	78,806
8410.2	Patellar tendon	0.001	28,803
8502.2	Tarsus disloc	0.001	148,975
8506.2	Hip dislocation	0.000	36,053
8508.2	Knee dislocation	0.001	28,803
8514.2	Calcaneus fracture	0.000	148,975
8516.2	Fibula fracture	0.000	184,386
8516.3	Fibula fracture	0.001	237,203
8518.2	Femur fracture	0.115	205,639
8518.3	Femur fracture	0.115	237,203
8520.2	Foot/ankle fx	0.003	148,975
8522.2	Metatarsal fx	0.000	148,975
8524.2	Patella fracture	0.000	213,165
8526.2	Pelvis fracture	0.000	263,777
8526.3	Pelvis fracture	0.000	482,065
8526.4	Pelvis Crush	0.021	482,065
8528.3	Sacroilium fracture	0.001	482,065
8530.3	Symphysis pubis	0.000	482,065
8532.2	Talus fracture	0.000	148,975
8534.2	Tibia fracture	0.000	184,386
8534.3	Tibia fracture	0.000	237,203
8906.2	Lower ext skin	0.001	11,522
8908.2	Lower ext skin	0.001	11,522
8920.2	Lower ext burn	0.002	78,806
8940.2	Degloving injury	0.002	78,806
8940.3	Degloving injury	0.002	120,078
9192.3	Inhalation injury	0.177	147,277
9192.4	Inhalation injury	0.356	258,648
9920.3	Burn 2nd deg	0.046	787,813
9920.4	Burn 2nd deg	0.288	787,813
9920.5	Burn 2nd deg	0.964	844,289
9920.6	Burn 2nd deg	1.000	844,289